THE INFLUENCE

OF

INVENTIONS UPON CIVILIZATION:

A PAPER

READ BEFORE THE CHIEFS AND COMMISSIONERS OF THE SEVERAL BUREAUS OF LABOR STATISTICS IN THE UNITED STATES, IN BOSTON, JUNE 20, 1885,

BY

CHAUNCEY SMITH.

BOSTON:
WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
18 POST OFFICE SQUARE.
1885.

V.—717

Tech. E

18 Apr. 1893

E. H. Hall

Cambridge

THE INFLUENCE OF INVENTIONS UPON CIVILIZATION.

In Westminster Abbey, that place where England honors her great men with burial, and records their names and achievements, there stands a monument bearing this inscription from the pen of Lord Brougham, who esteemed it one of the greatest honors of his life that he was called upon to record the nation's appreciation of the man in whose honor the monument was erected: —

"Not to perpetuate a name
Which must endure while the peaceful arts flourish,
But to show
That mankind have learned to honor those
Who best deserve their gratitude,
The King,
His Ministers, and many of the Nobles
And Commoners of the Realm,
Raised this monument to
James Watt,
Who, directing the force of an original Genius
Early exercised in Philosophic research,
To the improvement of
The steam engine,
Enlarged the Resources of his Country,
Increased the Power of Man,
And rose to an eminent place
Among the most illustrious followers of science
And the real Benefactors of the World."

The world has always paid homage to its distinguished warriors, statesmen, orators, poets, philanthropists, artists, historians, travellers, and to all who have left the impress of their works upon the history of mankind.

It is not until recently, however, that inventors have received a large share of these honors. As a class, they hardly had an existence till within a hundred years. Within that time they have risen to the highest place among those who, in the language of the eulogy I have just quoted, best deserve the gratitude of mankind, and by their works they have made greater changes in the face of society, and in the relations of civilized man to the physical world than all the warriors and statesmen who have flourished since the commencement of the Christian era.

I am not unmindful, in making this statement, of the great changes that followed the introduction of the Christian religion, or the advent of Mohammed and the rise of his religion, of the consequences which followed the establishment of great empires like that of Charlemagne, or of the results of geographical discovery, as in the discovery of America or of the passage to India.

I am well aware of the difficulty of comparing the magnitude or importance of such things, for instance, as the art of printing, the steam-engine, or the railway or telegraph, with a new form of religion or the establishment or overthrow of an empire, or the introduction of new forms of government. One man may attach much higher importance to some of these things than another would do, and a very much higher importance to them at one period of his life than at another.

It may seem absurd to some persons to make any comparison, for instance, between the benefits flowing from the introduction of Sabbath schools and those which have followed the invention of friction matches; between the results due to the invention of spectacles and the consequences which followed the reformation. And yet it is easy to see that each of these things must have had an important influence upon the physical, social, and moral condition of men, upon their habits of thought and of living, and upon their comfort and happiness. There is, therefore, some just relation between the value of these things to men, and it will not be unprofitable to spend a little time in considering how much we owe to inventors for what we have and what we are.

It is my purpose this evening to briefly bring into view, if I can, the service which inventors have rendered the world, and the part which inventions play in the moral and social condition of man. I shall point out in some cases the extreme simplicity of the inventions, in others the wonderful results which have flowed from them.

I shall refer not merely to what are called great inventions, but to some which seem to be very small. I shall very likely speak of nothing with which you are not all more or less familiar, but I may possibly suggest reflections which are interesting but which seldom come to our minds, for the very reason that we are so familiar with the things to which they relate, and I think that I may be able to show that there are no other men to whom the world is so much indebted as to its inventors, no others who so well merit its honors and deserve its gratitude.

We do not often stop to think how little man has or enjoys, that is not the fruit of invention. Things which man has long had we have ceased to think of as inventions, and we are apt to apply that term only to modern things — to things the origin of which we know. Yet it will be hard for any of us to name anything which we use or enjoy which is not an invention, or the subject of an invention, in its adaptation to our use.

The air we breathe and the water we drink are provided by nature. But we drink but very little water except from a cup or vessel of some kind, which is a human invention. Even if we drink from the shell of a gourd, we are using a thing which, in the shape we use it, is a human contrivance, and the contrivances which man has devised for obtaining water and distributing it, have been among the most wonderful and ingenious of any which have occupied the human mind. Bountifully as nature has provided water and placed it within the reach of man, yet we do in fact get or use but little of it except by the aid of inventions.

The air surrounds us at all times and we cannot help using it if we would; but if we want it either hotter or colder than we find it, we must resort to some invention to gratify our want. If we want it to blow upon us when it is still, we must set it in motion by some contrivance, and fans

among other things have been invented for that purpose. A large amount of human ingenuity has been expended upon devices for moving air when we want it moved, upon fans, blowers and ventilators.

How small a part of our food do we take as animals do, in the form provided by nature, and how very large a share in some form contrived by man! We drink infusions of tea or coffee without thinking that the compounds are human inventions. How large a place the milk of the cow has in the food of man, but how little of it could he have but for a multitude of contrivances! We think of butter as we do of milk, that it is a production of nature; and so it is, but its separation from milk is an invention which has been followed by a host of inventions to effect the separation easier or better.

Sugar is a production of nature, but little known a few hundred years ago. Separated from the plants in which it is formed, it is an invention of man. The savage who first crushed some kernels of wheat between two stones, and separated the mealy interior from the outer skin, invented flour, and the human mind has not yet ceased to be exercised on the subject of its improvement.

Probably the earliest inventions of man had reference to the procuring and preparing of food, and the ingenuity of man is exercised even now upon it more eagerly than ever before, and the power of man to produce food has been increased during the last fifty years more than it had been for a thousand years before.

Fifty years ago, a large part of the wheat and other grain raised in this country was cut, a handful at a time, with a sickle, and a man could not, as a rule, reap more than a quarter of an acre a day. An instrument called a cradle was beginning to come into use, and with that a man could reap about two acres.

Within fifty years inventors have given the world the reaping machine, with which a man and two horses will cut from fifteen to twenty acres a day.

Fifty years ago the grain was almost wholly threshed from the straw by pounding it upon a floor with a flail. If I remember correctly, a man sometimes received one bushel in

ten for threshing, and from ten to twenty bushels must have been a day's work.

Now a machine will thresh out hundreds of bushels in a day at an expense of a very few cents a bushel.

Inventions have changed the meaning of words. When I was a boy, a reaper was a man who reaped grain with a sickle, and a thresher was one who threshed it with a flail. Now, reapers and threshers are machines driven by steam or horse power.

For what part of our daily bread are we not indebted to inventions? Some of the fruits of the earth we eat as nature gives them to us, but how much even of them do we take directly from the tree or shrub or plant which produced it, and eat without the aid of invention?

All our animal food comes within our reach and is prepared for use only by the aid of inventions.

Hooks and nets and spears give us all we have of fish. The fish-hook is a very simple contrivance. Is it a great invention or a small one? If the fish-hooks should all be suddenly destroyed, together with the ability to make them, would not the loss of the invention be a greater calamity than any which has befallen the world for a thousand years? If so, were not the inventors of that instrument, and those who have improved it, real benefactors to the world?

Could we get along without needles? Could we give up pins without a sigh? Are knives and forks and spoons a necessity? They are all among the simplest things that man makes, yet he has not obtained them without a great deal of mental labor; without the exercise of powers of invention of a high order.

It is less than fifty years since the little articles called matches have come into use. They are now so common and so cheap that we use them almost as we do air and water, without thinking at all of their real value. How few there are of us who do not use them every day and many times a day, and how inconvenient it would be not to have them! But when I was a boy, nobody had them; nobody could have them, for they did not exist. In the country houses, at least, the greatest care was exercised not to let the fire go out upon the hearth, because in such case it became neces-

sary to send to a neighbor's, often at a distance, for a fresh brand. Every night the live coals upon the hearth were carefully buried in the ashes to preserve them alive for the morning. In spite of this precaution, the fire was often lost. I have been sent many a time, in such cases, to a neighbor's in a cold morning to get a burning brand to start the fire at home anew. Nobody now thinks of taking any pains to preserve a fire, for it is easier to start a new one with a match than to preserve an old one. A very common way of lighting a candle in the house when darkness came on was to take, with the tongs, a coal from the fire, — wood fires were then used — and blow it, applying the wick of the candle to it at the same time. Sometimes it could be lighted very readily, but oftentimes it could be done only by the exercise of a good deal of skill and patience. A great deal of vexation and trial of nerves and temper has been saved to the world by the invention of matches and the comforts of our homes increased in many ways. Perhaps, therefore, the comparison I suggested between friction matches and Sunday schools is not so incongruous after all.

There were some devices known in those days for obtaining a light or fire artificially, but they were inconvenient, somewhat expensive, and not in general use. The tinder-box was one of them.

A gentleman not much older than myself told me not long since that when he was in college one of his classmates was rich in the possession of a tinder-box by means of which he could strike a light and a fire in case of emergency, and he gave me a humorous account of the process of striking a light, involving considerable skill, much patience, and, as he said, some swearing.

A great many boys have been taught in Sabbath schools not to swear, but a great many more have doubtless, by the use of friction matches, escaped numerous occasions and temptations to swear, and wives have no doubt by this invention been saved from innumerable scoldings for not covering up the fire properly at night.

There is one curious fact about matches which I do not remember to have seen mentioned. We speak of them as a recent invention, but they are only an improvement upon a

very old invention. Travellers among savages have generally, if not universally, found that they possessed the art of procuring fire when they wished, by rubbing two pieces of wood together till the heat generated by the friction between them caused one of them to take fire. It is described as a pretty crude way of working, calling for considerable skill and some labor and patience. Perhaps the date of the invention may go back to the earliest use of fire by man. Yet the invention itself is essentially that which we practice when we strike a match. We rub the match upon another substance and the heat generated by the friction between the two causes the match to take fire. The improvement which the civilized man has made upon the invention of his savage ancestor is to coat the end of a piece of wood with a little composition of matter which takes fire at a lower temperature than the wood itself, and burns more rapidly. Simple as the improvement is, it took the world a long time to get it, and its inventor made a most important contribution to the comforts of man.

I was forcibly impressed a few years ago with the value to the uncivilized man of the simplest inventions of the civilized man, as I watched an Indian at Lake Superior at work upon a birchbark canoe. He had for tools only a knife, a hammer, and an awl, but I suppose he must have used a hatchet to procure the wood and bark of which the canoe was built. It was slow work even with these tools, and it was difficult to believe that he could have built the vessel with the blunt instruments with which his ancestors had to be content before they came into contact with the white man. What an acquisition the white man's fish-hook must have been to the Indian!

Fifty years ago a large part of the people of this country had no other resource for artificial light than the tallow candle. I remember it, and the vexations attending its use, the difficulty of lighting it by a coal of fire, the constant snuffing it required to make its light tolerable, and its constant tendency to melt and besmear everything in its vicinity. I venture to say that any of you would consider it an intolerable hardship to be compelled to use it and nothing else. Those who used oil lamps got a little better light, but not

much less discomfort. Gas was used only in the large cities. But the inventors have been busy in providing a new material for illumination and the means for using it and in cheapening their production; and now in kerosene and in kerosene lamps, both of which have been called into existence within thirty years, the poorest people can enjoy, at the most trifling expense, a light better far than anything which anybody could command at any price before the invention of gas less than a hundred years ago.

Can we estimate the comforts of the homes of the country due to these inventions? Can we estimate the greater value of the evening hours for work, or study, or reading, which these inventions have given them?

I remember that my mother had a vial of what she called rock oil, which she thought very good for sprains or bruises. It was said to have come from Western New York. I now suppose it to have been petroleum. Petroleum has been known to man for a long time, but it had no value till it came under the hands of the inventor. He has made a worthless article a blessing. Invention marks every step of its history. Petroleum in this country lies deep in the earth. By the aid of recent inventions man reaches it. By their aid he stores it, for it is a dangerous and difficult article to keep and transport. By invention, man has changed its character. And now, not only this country, but the whole world is lighted by this new material. Yet all the invention which has been bestowed upon it would have been wasted, but for another class of inventors and another line of inventions. The lamps had to be invented or improved, and hundreds of men have been engaged on their improvement for years.

And now inventors have entered a new field and given us a light for our homes and streets almost as brilliant as that from the sun itself, from that agent which, since the world began, has lighted up the sky in angry flashes only to alarm timid and superstitious man.

It is a curious and interesting exercise to take any common article of daily use and inquire how much invention has been involved in its production: what inventions have preceded it; what ones, if any, it has supplanted, and what ones it

gave birth to; what consequences followed its introduction, and what part it plays in the welfare of man.

The inquiry soon becomes a bewildering one.

Take paper, for instance. I believe we are indebted to the Chinese for its invention. Do we ever think of it as one of the great inventions of man? Why, it is nothing but rags ground up in water to a pulp, spread out in a thin sheet and dried. I think the art of making paper has been known in Europe less than a thousand years. It has taken the place of parchment for writing. It made the art of printing possible. It made the newspaper possible and especially the daily paper. The multiplication of pictures by engraving could not be carried on without it, nor the modern art of photography, to which I shall refer again. We attach great value to a system of general education as one of the most important agencies of modern civilization. But the first requisite of such a system is cheap books, and for these, paper is the only thing we could use. Would any of you undertake to enumerate within the next half hour all the uses to which paper is put? Would you undertake to name and describe all the kinds that are used?

Paper is largely made of rags. Rags presuppose the existence of cloth. Cloth is the product of two distinct inventions, spinning and weaving. Spinning and weaving are very old inventions, but even in their simplest form they involve the use of still older inventions. Whatever material is used for paper, a long line of antecedent inventions is involved in its use.

Paper must, I think, rank as one of the great inventions of man, and if the heathen Chinese had given the world nothing more than this, he would have made no small contribution to the progress of civilization.

I have said that paper is made from rags, and that cloth implies the arts of spinning and weaving. But it also implies much more. To me, one of the greatest marvels of human industry is a yard of cotton cloth at the price at which it is sold. The price of a yard of cotton cloth of the kind called print cloth, and which when printed becomes calico, is less than four cents, and the cotton itself costs half this sum. What inventions are involved in the raising of the cotton and

its transportation to the mill where it is to be converted into cloth! Of course we all think of the cotton gin, because that invention was made with special reference to the production of cotton, and has been much referred to as a striking example of the results which flow from an invention.

But the gin comes into use only after the cotton is grown. Of course the common agricultural inventions are used in raising cotton; the plow, the hoe, the machinery by which the plow is made, the arts of making iron and steel, including the machinery employed, the harness for the horse or mule which draws the plow, and the art of tanning the leather of which the harness is made. Recently, planting or drilling machines for planting the seed have come into use, and artificial fertilizers — the product of the chemist's art — and the mechanism for distributing it over the ground. Even after the plant has begun to grow and before it is ripe, invention must often be called into play to protect it from the ravages of insects, and not a few devices, mechanical or chemical, have been called into existence for this purpose.

The ripe cotton balls are still picked by hand, though inventors are busy with the problem of picking it by machinery. It is gathered into baskets or bags, themselves inventions, to be transported by a cart, another invention, to the gin house, still another invention, where it comes under the operation of the gin to separate the cotton from the cotton seed.

Would you like to know what the cotton gin has done towards making cotton cheap; towards enabling enough to be sold for two cents to make a yard of cloth? An acre of ground is expected to produce at least one bale of cotton, which weighs 400 pounds or over. Before the cotton gin was invented, a man could pick about four pounds and a half of cotton from the seed in a day. So that it took a man about ninety days to separate the cotton which he could raise on an acre, from the seed.

Whitney invented the cotton gin, and with it a man could separate seventy pounds. In other words he could do the work in six days which before took him ninety days. The invention was made less than a hundred years ago but inventors have been busy with it ever since, improving it year by year, and now it turns out 4,000 pounds a day. In other

words, a single machine will do the work of about a thousand men.

As soon as the cotton is through the gin it must be pressed into bales, for the cotton is a light, bulky article which cannot be transported without confinement and a great reduction of bulk. So another invention is required, the cotton press. Some of these presses are wonderful machines. They embrace a steam-engine, a force pump and a hydraulic or hydrostatic press and give a pressure of 4,000 pounds to the square inch.

The cotton bale is surrounded by a coarse cloth called gunny cloth, itself the product of another line of inventions, including the arts of spinning and weaving, and made by special machinery. The bale must also be hooped with iron hoops, involving again the inventions pertaining to the manufacture of iron, but in addition the machinery for rolling it into thin and narrow strips, and I think this embraces the art of rolling iron into round bars and drawing it into wire.

These hoops must at last be fastened around the bales, and that has called for the invention of peculiar fastenings called cotton-bale ties.

At length, through all these inventions, we have the cotton ready for market and transportation to the factory, where it is to be made into cloth.

This demands the use not only of the cart or wagon, an old but important invention, but the railroad, the car, and the locomotive or the steamship, or perhaps both of them. It is bewildering to think of the inventions involved in these, and I could not even enumerate them in the time I have, if I knew them all.

When the cotton reaches the factory, an invention stands ready to unload it from the cars and deposit it where it is to be used. The iron bands are removed by some instrument invented for the purpose, and the cotton is released from its confinement. It is submitted to machinery to free it from dirt and restore it to something of its original light, flocculent character, and it then enters a machine which spreads it out into a long sheet like cotton batting. This sheet in turn is stretched out into a long, soft rope, called a roving. Successive machines, four or five in number, I

believe, extend the roving and make it smaller, till it is smaller than a common pencil. It then goes on to a spinning-frame and is twisted into a thread ready for weaving. Our two cents' worth of cotton has been drawn out into a fine thread more than 7,000 yards long, each inch of which has more than forty twists in it.

Shall I stop to tell you what man has achieved in the art of spinning? The art, as you know, is a very old one. Its invention lies back of the records of history. It was practised a long time in its primitive form as a mere manual operation. The wool or flax or cotton was carried on a distaff. The thread was drawn out and twisted by means of a spindle held in the left hand, by which it was set to whirling while the fibres were drawn out of the mass and guided by the fingers of the right hand. The art was practised in this crude way for ages, and it is so practised now in some countries.

A book which describes this process says it was an obvious improvement to set the spindle in a frame and set it whirling by a band passed round it, and around a large wheel which was in revolution. But it was not so obvious that anybody, through long years, thought of it till about 350 years ago. I believe this improvement which constituted the common spinning-wheel was invented in Germany. A woman could spin with it much faster than in the old way, but she only kept one spindle employed. A little more than a hundred years ago the spinning-frame was invented in England, in which a number of spindles were set and kept in operation at the same time. At first only eight spindles were used, but now several hundred are used in one frame.

There were three leading inventors at this early date who each made important improvements in spinning — Hargreaves, Arkwright, and Crompton. With a common wheel a woman can draw out a thread about four miles long in a day. On a modern spinning-frame she can take care of 800 or more spindles and spin threads the aggregate length of which would be more than two thousand miles.

On these machines cotton yarn has been spun so fine that one pound of cotton would make a thread 335 miles long,

and as a feat threads have been so fine that a pound of cotton would reach nearly 5,000 miles.

To go back to our two cents' worth of cotton, which has been converted into yarn. It is subjected to the action of several machines before it reaches the loom, where it is converted into cloth. Weaving, like spinning, is old, and some sort of machinery has always been employed in the process, but the power-loom of our factories is a modern invention. I sometimes think it is the most wonderful machine used. To make one yard of cloth, a shuttle carrying the filling thread is thrown across the web perhaps 1,500 times at the rate of a hundred crossings a minute.

There are looms which weave cloth more than three yards wide. There may be nearly 10,000 warp threads in cloth of this width and 5,000 filling threads in a yard carried across the web at the rate of nearly a hundred throws a minute.

The art of printing has always been recognized as one of the great inventions of man. It is over 400 years old, but after its first introduction very little improvement was made until the present century. Since then it has presented a rapid succession of the highest efforts of mechanical genius. I shall not attempt to follow their history or describe their character; but it is interesting to know that they have been made almost wholly by English or American inventors, and that more has been done in this country than in England. The wonder of modern printing is that it can be done so cheaply. You have all seen the series of publications by the Harpers called the Franklin Square Library. I bought a copy for ten cents, the regular price. It contained thirty-six printed pages. I had the curiosity to estimate the number of words on a page and calculated it roughly at 2,000. That would give for the whole book 72,000 words, all for ten cents. Can you form a conception of the number of inventions which has made such an achievement possible? I think a modern daily newspaper is, however, one of the greatest wonders of the age.

I buy a morning paper, the "Boston Herald," for instance, for two cents. I read it on my way to Boston in the horse-cars and abandon it at the end of the trip, not because it is worthless, but because I have obtained from it what I wanted

and it will not pay to preserve it for any other person or for future use. Now, what do I buy for my two cents? The physical thing that I buy is a sheet of paper and a certain amount of printers' ink impressed upon the surface of the paper in shape of letters and words. It is a wonderful fact that man can spread out the fibres of various vegetable substances into a thin, uniform sheet like that of paper, that he can cover such sheet with signs which can be made to express every passion or emotion of the human heart, every conception of the mind, and every fact in nature! Scarcely less wonderful than the fact that he can do it at all is the fact that he can make such a sheet of the size of the "Boston Herald" for two cents. It would take a volume to record all the inventions which have been made relating to the manufacture of paper alone to make such a result possible, and another for the inventions relating to printing. But the inventions relating to paper and printing would not of themselves enable "Boston Heralds" to be printed. The "Herald" is not made and sold for the paper and ink of which it consists, but primarily for the news it contains of what has taken place only the day before all over the world. You will find in the "Herald," as you know, or any other morning paper, day after day, the news of what took place the day before, not in Boston or vicinity alone, or even in Massachusetts or New England, or in this country, but in Europe, Asia, and Africa as well.

Through the potency of modern inventions you may perhaps to-morrow morning shudder over the horrors of a railway accident taking place at this moment thousands of miles away. Not till within a short time, and only through the works of the inventor, did a railway accident become possible.

You may perhaps read that a palace of the Emperor of Russia has been blown down with dynamite. Will you stop to think that dynamite is a new invention or that the telegraph which brings the news was unknown fifty years ago?

The paper may tell you that Mr. Edison has perfected his electric light and is at this moment illuminating many cities, and you will speculate upon the effect that the announcement will have upon gas stocks, but will it occur to you that

neither gas stocks nor gas was known a hundred years ago, and that till within less than half that period man had but little more control of electricity than he has now of earthquakes?

Now, consider for a moment how this facility for transmitting intelligence must affect society in one of its most important aspects. A great calamity falls upon some distant city or community. If the news of it reached us, as it would have done a century ago, only after the lapse of days, or weeks, or months, and if friendly help can be given only after the lapse of a similar period, we may be touched with pity, but there will arise but little sense of sympathy or generosity or duty.

But when the intelligence reaches us almost at the moment of the occurrence of the event, and we are conscious that it lies in our power to help, the sympathies of thousands are awakened, their generous impulses are touched and they recognize a moral obligation to bestow needed help, because it can be made immediately available. The duty springs from the ability and the ability is the fruit of invention. It may seem a strange assertion to many persons, but I believe it can be shown to be true, that the development of the moral nature of man has been as directly dependent upon invention as has his physical comfort.

The relation between astronomical and mathematical investigations and navigation has been long recognized, but this relation is dependent upon the observation of the apparent position of heavenly bodies at given times, and these observations are in turn dependent upon telescopes and upon clocks and chronometers, both modern inventions. The working of the railroads of the country is hardly less dependent upon the timekeepers we possess than navigation is upon chronometers. Let any one ask himself how the railroads of this country could be operated if our only timekeepers were sun-dials, hour-glasses and the clepsydras of the ancients, and he will soon see that the construction of the time-tables of our railroads and the operation of the roads in conformity with them would be impossible.

Mr. Atkinson will tell us what it costs to transport a barrel of flour upon our railroads from Minneapolis to Boston,

and approximately what the saving is by the railroads over the old modes of transportation, but can he tell us what part of that saving is to be credited to the clocks at the railroad stations and to the watches which the conductors carry in their pockets?

The late Judge Curtis said to me several years ago that the introduction of railroads had made a great change in the habits of the people as to punctuality in keeping appointments; that before their introduction nobody thought of being punctual to a minute, or even to an hour. Nobody thought of being "on time" till the railroads presented the alternative of being so or of "getting left."

One can now easily see that before the general use of clocks and watches, punctuality, as it is now understood among business men, could hardly have been reckoned as a duty. This is one illustration out of many more important ones where our social or moral obligations have arisen from or have been changed by physical inventions. By observations upon the laws or conditions of health by means of recent inventions and only possible by their means, we have learned how to counteract or prevent the introduction or spread of many diseases, and in consequence of this men recognize the duty to adopt and enforce many regulations in society for which no reason could be found a few years ago.

How could we live without glass? It enters so largely into the list of things we consider absolutely necessary, to say nothing of its uses for convenience or luxury, that we should almost as soon think of living without light or heat, without air or water, as to live without this cheap substance made principally out of the sand under our feet. Can any one tell what civilization would be without it? It would certainly be a very different thing from what it is.

We talk of the fireside and the influence it has upon families and social life, but the window plays a more important part in our homes than the fireside. The invention of glass goes back to a very early period, but its general use for windows is comparatively recent. Accustomed as we are to glass windows, it is difficult for us to conceive how a house could be lived in with comfort without it.

There is another use of glass, resting upon a very simple

invention, which plays a very important part in the comfort of man and the value of his labor, and which contributes wonderfully to our knowledge of nature and the universe.

Ever since man was capable of observing things around him, he must often have seen that a straight stick thrust obliquely into the water appeared to be bent at its surface. But it was a long time before man learned the value of this fact; but at length the lens was discovered. The invention consisted simply in the form given to a piece of glass; in giving to one or both of the surfaces of a disk of glass a curved form. This we know forms a lens, and a lens has become one of the most valuable devices known to man, but it was a long time after its invention before it became of much value.

A thousand years elapsed after the invention of the lens before it assumed an important place among the instruments employed by man. But man learned its value at last. Lenses may be made of other materials than glass, but for all practical purposes they are made of glass, and no other material will supply its place.

I alluded to spectacles as a valuable invention. I have never seen any attempt to estimate its value. I do not know that I ever heard the inquiry made. And yet when we remember that nearly every person above the age of forty-five, and very many below that age, use glasses, we see that they must enter largely into the sum of our comforts. How many persons would be deprived of the pleasures and benefits of reading and writing during a large portion of their lives but for this simple invention. How many kinds of labor would be performed badly and with great discomfort but for these devices. At what disadvantage literary labor would be carried on without them! For how many delicate handicrafts would men and women become unfitted in their later years but for them! At what discomfort and inconvenience would domestic needlework be performed in their absence. How much trial of the patience is saved by their use. I doubt not our tempers are much better in old age for these helps.

But the value of the invention of the lens is not limited to its use for spectacles. From it has grown up those won-

derful modern instruments, the telescope and microscope. Through the former has come a large part of our astronomical knowledge, which has a great commercial value from the security it gives to man in navigating the oceans. It has also a high moral and mental value from the field it opens to the exercise and training of the powers of observation and imagination; from the new conceptions it has given us of the immensity of creation and of the power which gave it birth. I wonder if any man can rise from a contemplation of the facts, the mysteries and magnitudes of the universe, revealed to us by the telescope and spectroscope, without repeating to himself, with a new sense of its significance, the question, "What is man that Thou art mindful of him, or the son of man that Thou visitest him?"

But while the lens thus opens up to man in the boundless regions of space a universe which no stretch of the imagination could give him a glimpse of without it, it opens up to him also a no less wonderful universe in regions which, by reason of their littleness, lie equally beyond his powers of observation or the powers of his imagination.

It reveals to him the presence of life in forms as wonderful for their minuteness and activity and numbers as the sun and stars are for the mighty spaces they occupy and traverse.

This little device, then, of a piece of glass formed with curved surfaces, which a boy may fashion upon a piece of sandstone, not only enters into the daily use of man, ministering to his comfort and prolonging his power to work efficiently, but in no figurative sense it enables him to behold a new heaven and a new earth. It opens to him the most wonderful secrets of nature, and gives him new conceptions of the vastness of the universe and of the magnitude of the forces involved in its mechanism. The ancients believed that the sun was only a few miles away, a few thousand miles at most, but the telescope has enabled man to learn that the sun is 92,000,000 of miles away from us; that the earth, 8,000 miles in diameter, in his yearly journey around it, travels 600,000,000 miles at the rate of nearly 20 miles a second.

What conception of infinite power could the imagination, unaided, give to man, which could in the least approach that which is involved in this movement of the earth!

But we know through the telescope that this power, mighty as it is, is but an infinitesimal part of that which is actually displayed in the regions of space which only within recent years and by the aid of a multitude of inventions have been opened to the observation of man.

Upon glass and the lens man is dependent for the use of another recent invention, which now that we have it we would not willingly do without.

A beautiful art has come into existence since I was a young man, which gratifies one of the strongest desires of the heart and ministers to the social pleasures of every family and circle of friends. I well remember when the newspaper first announced that a Frenchman had invented a way of taking pictures by the help of the sun. Before that time very few people could have likenesses of their friends, living or dead. The face of a friend could only be seen when he was present. When absent, memory must do what it could to preserve the features. Only the rich, and not a large proportion of them, could command portraits of themselves or friends. Into what houses will you now go where you do not expect to find likenesses of whole families, and whole circles of friends? Very poor indeed are those who cannot and do not find the means of procuring and preserving pictures of those they love. Can any one measure the amount of gratification which the world has received from the practice of the wonderful art of taking pictures from nature, through the agency of a few chemicals spread upon a sheet of paper or of silver, and of the rays of light concentrated by means of a lens? There has been received from it mental, artistic and moral culture. The invention has opened up a new field of investigation and research to the labor of the chemist and to the student of nature. From the first announcement to the world, to the present hour, a host of inventors have been engaged in perfecting and improving the art, enlarging the field of its applications, and studying the laws of nature upon which it rests. The boundaries of human knowledge in more than one department of physics have been greatly extended in these efforts. Astronomy has received important aid from it, and by its help we get not merely pictures of what exists in the heavenly regions but records of what is there taking place.

This art has even come to play an important part in the administration of justice and in the protection of the community against crime. By its aid criminals are detected, watched, and convicted. Forgeries are proved or disproved by its use. It finds an important place in the ordinary business of commerce and the mechanic arts. By its aid, copies or representations of all valuable works of art are placed within the reach of multitudes who, otherwise, would know nothing of them or know them only through inadequate verbal description. The improvement of the public taste in relation to art by the knowledge of works of art which has been thus diffused, has been very great.

Does any one doubt that this extension and this spread of knowledge of the works of art must tend to the improvement of man's moral nature? Can it be doubted that the social affections are quickened by the preservation of the features of friends and the interchange among friends and families of pictures of those who make up the family circle? Will not a boy absent from home, feel the influence of home more strongly when he looks upon the faces of parents or sisters, than he would if he could not thus bring them into his presence?

But all these benefits which the world reaps from photography have come to us from inventions. It is not the fruit so much of genius, as of that patient labor and research which is winning from nature, day by day, secrets far more valuable to man than all her hidden treasures of gold and silver.

Within the memory of men not very old, a new power has, by the genius of inventors, been trained into the service of man. This power is electricity. It has always, as we now know, been present in many of the phenomena of nature, exhibiting itself most strikingly in the lightnings of the thunder storm, revealing, as man believed, the presence of a mysterious power which might be destructive, but which never could be useful to man.

A trifling incident revealed to an observing man in Italy, the fact that when two metals and the leg of a frog were made to touch, the muscles of the leg were contracted. This was a little more than a hundred years ago. This led to the invention of the galvanic battery, an instrument by which

man was enabled to generate electricity for his own use. But many years were still to elapse before man could turn the instrument to much service.

Forty years later, another observer noticed that when a wire which was carrying a current of electricity generated by a battery was placed near the needle of a compass it turned the needle one way or the other on its pivot. A few years later, Faraday discovered that if such a wire was wound around a piece of soft iron, it made a magnet of the iron. Out of these simple facts have arisen the inventions of the telegraph, the telephone and the electric light. The oldest of these inventions, the telegraph, is only about forty-five years old, and there are many who can easily remember the feelings of incredulity and amazement with which the claim that the invention had been made was received.

Can any one calculate the influence which this invention is destined to have upon the condition of man? We think it has spread over the world with wonderful rapidity. And so it has. But the world has just begun to use it. Although we see telegraph lines spread all over this country, and we say and think that everybody uses the telegraph, yet the number of messages sent last year did not much exceed one to each two persons in the land, while the number of letters written, including postal cards, probably exceeded ten to each individual. When messages can be sent, as they most certainly will be, to any part of the land for ten cents or less, multitudes of people who never think now of using the telegraph except upon matters of pressing importance, will use it upon the most common occasions. How many times would the simple "all well" be exchanged daily between friends if it could be done for five or ten cents!

A multitude of inventors have been necessary to make the telegraph what it is, and its improvement was never going on more rapidly than to-day. I well remember how difficult it was for many persons to form an idea, when the telegraph was first invented, of the way it worked. It was not an uncommon belief that the paper on which the message was written was in some way sent along the wire to its destination. But the idea became familiar after a little time that the electricity only traversed the line and operated a mechanism

at the distant place which recorded the message in a new language, or delivered it directly to the ear, and people began to think that they understood how the telegraph was worked. But when inventors began to talk about sending two or three messages over the same wire, at the same time, the limit of belief seemed to have been reached, and people obstinately refused to believe that the thing could be done. But it has been done in more ways than one, and now there are numerous wires in the country over which four or even six messages are sent at the same time. As these inventions enable one wire to do the work of two or four or more, the wires which are wanting are called by the telegraph people "phantom wires." The improvement of the telegraph is taking other directions. On the common lines the messages are sent by the operator at the rate of about thirty or forty words a minute. But inventions are in progress, and are now being introduced, which will enable a thousand words a minute to be sent. Think of sending messages from Boston to New York over one wire, and recording them there, at the rate of a thousand words a minute! Few people speak at the rate of two hundred words a minute.

Those of us who are in the habit of receiving messages, often get them printed on long strips of paper. The invention used in sending messages in that way is one which enables a man in New York, by touching keys like those of a piano, to operate a printing machine in Boston or Chicago.

The highest achievements in telegraphy is undoubtedly reached in the ocean telegraph. It demanded a whole line of inventions peculiar to itself. A simple wire could not be used for a conductor. It would give out the electricity to the water so fast that none would reach the farther end to deliver the message, and the wire itself would be speedily destroyed. A coating must, therefore, be found for it which would at once protect the wire from the action of the water and keep the electricity from going off into the water. When such a coating had been invented, it was found necessary to strengthen the copper wire used for the conductor by the addition of steel wires, which must not touch the copper wire, but surround it, and this too must be protected by a coating. Then machinery had to be invented to combine the

copper and steel wires with the coating material into a cable. Other machinery had to be invented to deliver the cable from a ship as she sailed over the course where the cable was to be laid. Only the steamship could be used for the purpose, and thus the invention of the steam-engine gave to man the power to establish ocean telegraphs. New instruments of the most wonderful sensibility had to be invented both for sending and receiving the messages. A minute magnet carries a tiny mirror and is suspended by a thread so as to yield to the slightest impulse. A ray of light from a lamp falls upon this mirror and is reflected upon a screen some feet distant. This ray of light is the finger which the operator watches upon the screen. As the current in the wire varies under the action of the sending instrument, the magnet turns one way or the other, and the spot of light on the screen moves one way or the other and indicates the signals of the Morse alphabet to the operator and enables him to spell out the words.

Sometimes a fault is developed in the wire as it lies on the bottom of the ocean and signals cannot be sent. Does it seem possible that man can tell whereabouts on three thousand miles of wire, two miles under water, the fault is? He has invented instruments which enable him to do it, and to send a vessel to the very spot over the wire where the fault is, pick up the wire and mend it and return it to its resting place.

Some time before his death, in 1819, while resting from labor in his old age, James Watt, when asked to allow his fellow citizens to honor him with a seat in parliament, refused, saying that he had given employment to the better part of a million of men and had earned the right to rest from work. To how many millions of men since then has his invention given employment! In a life of Watt published many years since I find a statement that the steam-power of the world was equal to that of 400,000,000 of men, and this amount has probably been doubled since the statement was made. And yet the world has even now but just begun to reap the fruits of this invention. Each year witnesses the extension of its use.

About seventy years ago Robert Fulton, one of the great-

est mechanical geniuses of this country, applied the steam-engine to a boat and made the first trial of a ship moved by the power of heat in a trip from New York to Albany. Now every ocean is plowed by the steamship, and there is hardly a navigable river on the face of the globe that has not become a highway for it. A few years later, in 1825, George Stephenson invented the locomotive and gave to man the railroad, and now, sixty years later, we have 112,000 miles of railroad in this country alone.

I believe that no other Englishman has done so much for his fellowmen, so much to change the social and economical conditions of society, as George Stephenson.

Would you like to know how much the steam-engine has increased the power of man in Massachusetts? I can tell you what the locomotive has done. In 1878 the railroad companies of this State had 1,030 locomotives. The proportion due to the amount of their track in this State was 757, and the work they did was equal to what 913,545 horses could do on good common roads, and was equivalent to the labor of 5,481,270 laboring men, or to that of a population of nearly 20,000,000.

Now, in 1875, Massachusetts had only about 130,000 horses, and her population was a little more than a million and a half.

But this was not all that Massachusetts owed to the steam-engine. She employs it largely in steam vessels owned in the State or coming from abroad. What the whole amount of work done by these vessels was equal to I do not know, but it was large.

She also employed steam and water power in her manufactures equal to that of 1,912,488 men. The work done by the steam and water power was equal to what could have been done by hand power by a population of 7,400,000.

I think there are more than 20,000 locomotives in the United States. There would be more than that if all the roads were as well provided with locomotives as the roads in Massachusetts are.

Assuming that to be the number, and that they do as much work as they do here, and the work is equal to that of 25,000,000 horses, or to that of nearly 150,000,000 of men, or

to a population of nearly 500,000,000. I suppose the actual population of the United States is nearly 60,000,000. We see by this how much in this country alone the inventions of Watt and Stephenson have increased the powers of man. The imagination staggers under the figures.

Of course a host of other inventors have been concerned with the results I have given, but the results are none the less the work of inventors because there are many of them.

The steam-engine has entered into many other inventions, the steam-drill and the steam-dredge, for instance, which have given to man the ability to execute engineering works of the most extraordinary character.

The steam-hammer is another of the wonders of modern machinery which followed the steam-engine. One of the gods of ancient mythology was Vulcan, a blacksmith, who was supposed, I believe, to have forged the thunderbolts of Jupiter. What conception may have been entertained of his power or of the magnitude of thunderbolts, I cannot say, but probably he was never supposed to wield a hammer like a modern steam-hammer, weighing thirty-five tons, through a distance of ten or twelve feet, or to have executed any work like the forging of the propeller shaft of a modern steamship. But what ancient gods could not do, the modern inventor easily does.

The power of the steam-engine comes from heat; from the fire in the boiler. The fuel used is largely coal, stored ages ago in the earth. Fire has been long known to man and has been ready to do his work, and the iron and steel for engines had been long known. But not till the magic of the inventor had brought these things together, did man learn what power was lying ready to his hand.

A few years after Watt invented the steam-engine, and while he was laboring to improve it and adapt it to the various wants of the world, a wonderful military genius arose in Europe, who filled the world with his fame and made himself as large a place in history, perhaps, as man ever did. He played havoc with the nations of Europe, changed the boundaries of countries and their forms of government, and apparently raised France to the highest pitch of power. But he lived only to destroy. Measuring Bonaparte and Watt

by their works, and their works by the consequences which followed them, and which must stand as the greater fact in the history of the world? Which controlled most potently for his own time and for the future, the destiny of nations, and which most deserves the admiration and homage, not to say gratitude, of mankind?

I hear people not infrequently express the belief that man will soon exhaust the field of invention. The inventions of the last century have been so numerous and wonderful that to many minds it seems most likely that man will soon reach the limit of his power, or that he will exhaust the resources of nature. But there is little reason to fear that either condition can be reached for ages, if ever. It is as little likely that man will ever reach the limit of invention, as it is that he will be able to fix the bounds of the universe. Man makes inventions by combining the materials and forces of nature, so as to reach new results. Let any one consider how numerous are the materials which nature presents to the observation and use of man, how varied in kind and degree are the forces which are in constant operation, and how multifarious and intricate are the laws which govern their actions and relations, and then calculate, if he can, the number of possible combinations which can be made. I have seen the statement, which is no doubt true, that the fifteen blocks in the gem puzzle can be arranged in more than a million different ways. If this simple toy possesses such capabilities, what possibility is there that man can ever exhaust the field of nature? Wonderful as man's inventions are in number and character, they are at an infinite distance behind the works of nature. What a multitude of created things there are in nature, looking simply at species and varieties, and not at the individuals! How many kinds of plants and animals are to be found! What multitudes of reptiles and insects! No machine which man has invented calls into play such wonderful forces or is governed by such wonderful laws as the humblest plant on which he treads! Man is far enough yet from inventing a structure which shall build itself up from the earth, air and water, and scatter germs for its indefinite reduplication! He has succeeded in copying some of the products of nature, and he will achieve

still greater results, but in doing it he has but opened a new field of invention, one which only a few years before seemed utterly beyond his reach. He has enlarged the field of invention, not exhausted it. A striking instance of what man has done in this new direction is exhibited in the substance called alizarine. It is the substance which gives to madder its coloring quality. Not many years ago, madder was extensively cultivated in many countries to supply the demand for the arts. Now the article is made artifically from coal tar, and the fields where madder was cultivated have to be devoted to other purposes. Invention has taught man how to make indigo, and the artificial article is likely to supplant the natural product. Diamonds have been produced artificially. I have full faith that sugar will in time in like manner be produced artificially. Starch and oil may not unlikely be provided in the same way. Man now cultivates the silkworm which devours mulberry leaves and converts a large portion into a glutinous fluid which, when spun out into a fine thread, hardens and forms our silk. Man may yet learn how to extract silk directly from the leaves, and perhaps even produce the substance which the worm elaborates, and spin it into silk.

Since the telephone has shown that man, through the agency of electricity, can talk with his fellow-man hundreds of miles away, there are men daring enough to think that through the same agency man may yet see things at an equally great distance, so that you may not only talk from Boston to your friend in New York, but may actually see him as if face to face, and they claim that their attempts have been attended with some degree of success. Would you dare to say it was more unlikely that such a result may be achieved than that man should be able to transmit intelligence instantly three thousand miles through the depths of the ocean? Through long ages man remained unconscious of the presence and action of the forces of magnetism and electricity, but we now know that they are constantly present everywhere and incessantly active. What other forces may still be hidden from the observation of man it is impossible to know.

The present scientific belief is that the atmosphere is an

aggregation of infinitely small molecules, which really fill but a small part of the space the air seems to occupy; that through the unoccupied space these molecules are rushing at a high speed, hitting each other and the solid bodies around them and rebounding, and that what we call the pressure of the atmosphere, fifteen pounds to the inch, is really the bombardment of these molecules upon whatever arrests their course. The reason that all solid things are not swept away by this incessant pounding, is that the blows are struck in every direction, and so neutralize each other. But here is an ever present and ever active force, and if man should ever discover a way to make all the particles of a body of air move in one direction, he would have at every place on the surface of the earth an unlimited amount of power placed at his command.

But even if man should accomplish all this, there would still be an infinite distance between anything which he could devise or construct, and the organic structures which grow up around him; between the forces which he could wield and those exhibited in the operations of nature; and each step which he might take, while it would enlarge his knowledge, would at the same time bring him into the presence of new mysteries, and open up to him new problems for solution. Each new invention gives birth to a host of other new ones.

The steam-engine has been the study of inventors for a hundred years, and each year has witnessed improvements upon it, and such improvements are going on more rapidly than ever before.

About forty years have elapsed since Howe gave the sewing machine to the world, and thousands of inventions for its improvement or adaptation to new uses have been made and they are going on still. The same is true of reaping machines, spinning machines, looms, the manufacture of iron and steel, printing and telegraphy, and of almost everything used by man.

There is no sign that the work of the inventor is near its end, and those who believe, as I do, that he has been the chief agent in the progress of the world, have no reason to doubt that the world will be still more deeply indebted to him as the centuries go by.

There are now in force in this country more than two hundred and fifty thousand patents for inventions, the fruits to a very large extent of the mental labor of those who are called the laboring men of the country. Aside from the direct value of these inventions in promoting the comfort and increasing the wealth of the country, there is another factor to be considered, having the most vital relation to the industries of the country and its powers of production. This great number of inventions implies a high degree of intelligence and great mental activity in the great body of the people. It indicates trained habits of observation and trained powers of applying the knowledge which has been acquired. It shows an ability to turn to account the forces of nature and train them to the service of man, such as has been possessed by the laborers of no other country. It suggests as pertinent and most important the inquiry whether any other country is so well equipped for competition in production as our own; whether in any other country the laboring man is as efficient and his labor therefore as cheap as in our own; whether he does not exhibit the seeming paradox of receiving more for his labor than in any other country, and at the same time doing more for what he receives, — giving more for what he receives, and receiving more for what he gives.